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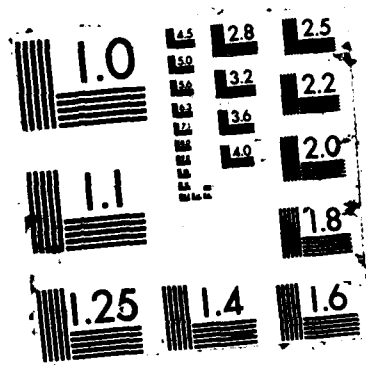
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Global Convection Patterns in the High Latitude

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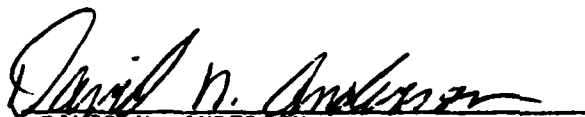
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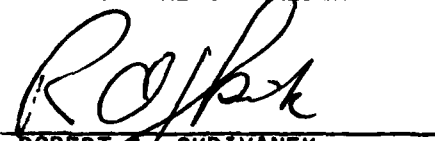


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19. ABSTRACT (Continue on reverse if necessary and identify by block number) Studies of large and small scale structures in the high latitude F-region plasma velocity and concentration have been undertaken. The large-scale plasma convection pattern has been examined using an extensive satellite data base to reveal a major dependence of the dayside configuration of the pattern on the y-component of the interplanetary magnetic field. A model has been constructed for periods of southward IMF that adequately mimics the observations. During periods of northward IMF much smaller scale structure is seen to dominate the observations. A smaller-scale convection pattern has been tentatively identified in the data for northward IMF. Of primary importance, however, is the existence of small scale structure associated with sun-aligned arcs that have dimensions in the noon-midnight-direction that exceed those in the dawn-dusk direction by a factor of 10. In addition to these properties of the convection pattern the formation of E-region structure by the presence of structure in the F-region has also been examined. <i>Keywords</i>				
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# TABLE OF CONTENTS

	<u>Page</u>
1. Introduction	1
2. Large Scale Electrodynamics During Southward IMF	1
3. Large Scale Electrodynamics During Northward IMF	2
4. Small Scale Electrodynamics	5
References	7
Publication Abstracts	8



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## 1. Introduction

During the tenure of this contract we have studied small and large scale electrodynamic properties of the ionosphere, both experimentally and theoretically. We have used many of our findings in the development of a mathematical model of the ionospheric convection at high latitudes. This model is currently in use at AFGL in the study of plasma transport and plasma patch formation in the polar cap. All the work we have undertaken, with the exception of computer code development has resulted in publishable material that has or will appear in professional journals or books in the field. A list of publications and preprints or reprints of the material forms the body of this report. Rather than a detailed description of the work here, we have chosen to highlight our major achievements and include reprints or preprints of the articles produced in order to provide as much detail in any area as is desired.

## 2. Large Scale Electrodynamics during southward IMF.

We have conducted several studies and reviews of satellite and radar data bases to determine the geometry of high latitude convection cells and their dependence on the interplanetary magnetic field (IMF) when it has a southward component. We find a general convergence of opinion regarding the geometry of a two cell convection pattern consisting of one cell with a circular perimeter and another more crescent shaped that surrounds it. The transition region in which dayside plasma rotates from sunward to antisunward is located in the pre-noon sector for both signs of  $B_y$  but the circular cell occupies the morning side when  $B_y$  is negative and the evening side when  $B_y$  is positive. Our work in these areas is contained in the papers 3, 4, 5, and 7 in the attached list. We have incorporated the findings into most current versions of mathematical models for the convection pattern and two extremes representing positive and negative

values of  $B_y$  are shown in Figures 1 and 2 respectively.

### 3. Large Scale Electrodynamics during northward IMF.

The IMF has a northward component about 50% of the time. During these periods the high latitude convection signature can appear organized or disorganized depending on a season and location in the polar region. We have studied many of the electrodynamic characteristics in an attempt to discover the effect of the IMF. The most radical difference in the high latitude region between southward and northward IMF is the appearance of discrete auroral emission features in the polar cap. These arcs usually emanate from the nightside auroral zone and can be identified with a unique convection signature and a unique plasma source when the precipitating electron energy exceeds 1 keV. These findings are described further in 9 below. Quite frequently the characteristic energy of the emission features can be quite low ( $< 600$  eV) and the arcs may only be visible with image intensified camera systems. In this case many of the plasma flow characteristics of the arcs are the same but the source for the plasma cannot be easily identified. We are currently trying to resolve such observations with coherent features in the magnetosphere.

In the dayside high latitude region the convection pattern during stable northward IMF periods can frequently be identified with three or four convection cells. Usually one of these cells has sunward and antisunward flow that may be associated with open field lines. However the identification of a 3-D flow pattern from satellite measurements usually requires an element of repeatability that is not always present in northward IMF data sets. Quite frequently the dayside convective flow can be reconciled with the possible drivers for convection during northward IMF but there is as yet no general convergence of opinion on the subject and an adequate mathematical model is still pending. Paper 10, describes in more detail, our findings in this area.

$P_{\max}$  23  $P_{\min}$  -37  
 $f$  -4 0  $B_y$  7 0

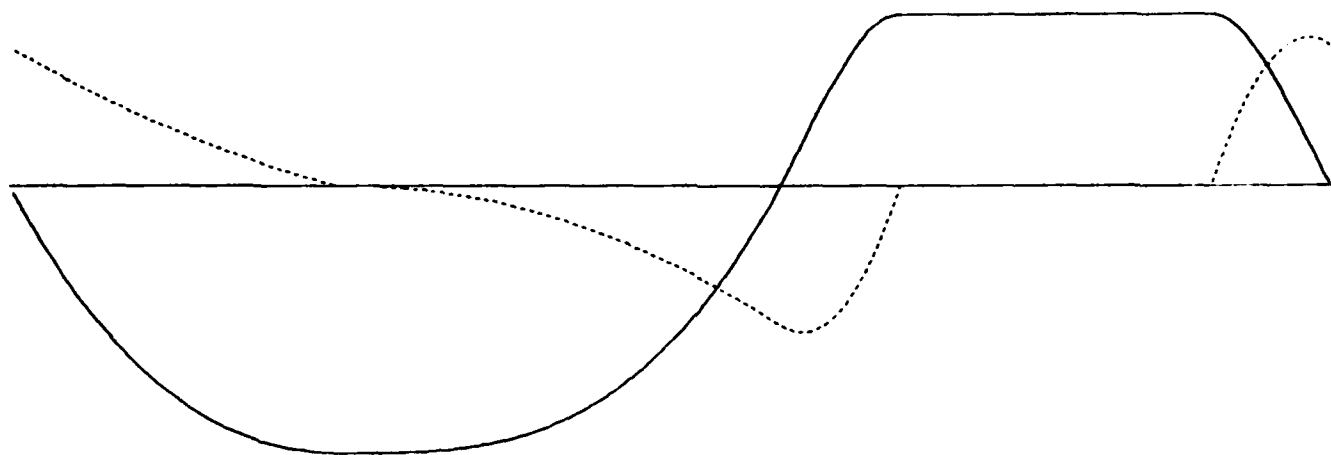
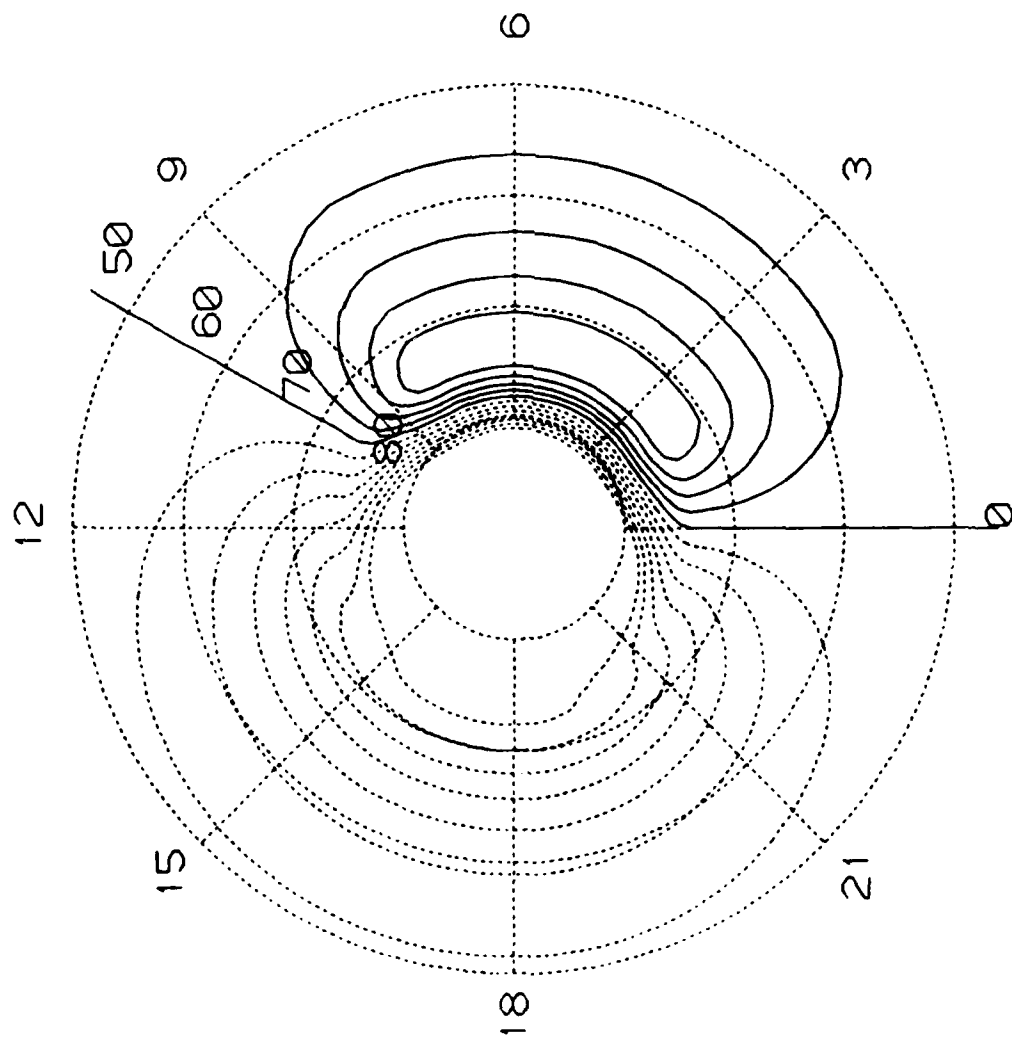


Figure 1. Model Convection Pattern for positive  $B_y$

$P_{\max}$  28    $P_{\min}$  -32  
 $f$  -4 0    $B_y$  -7 0

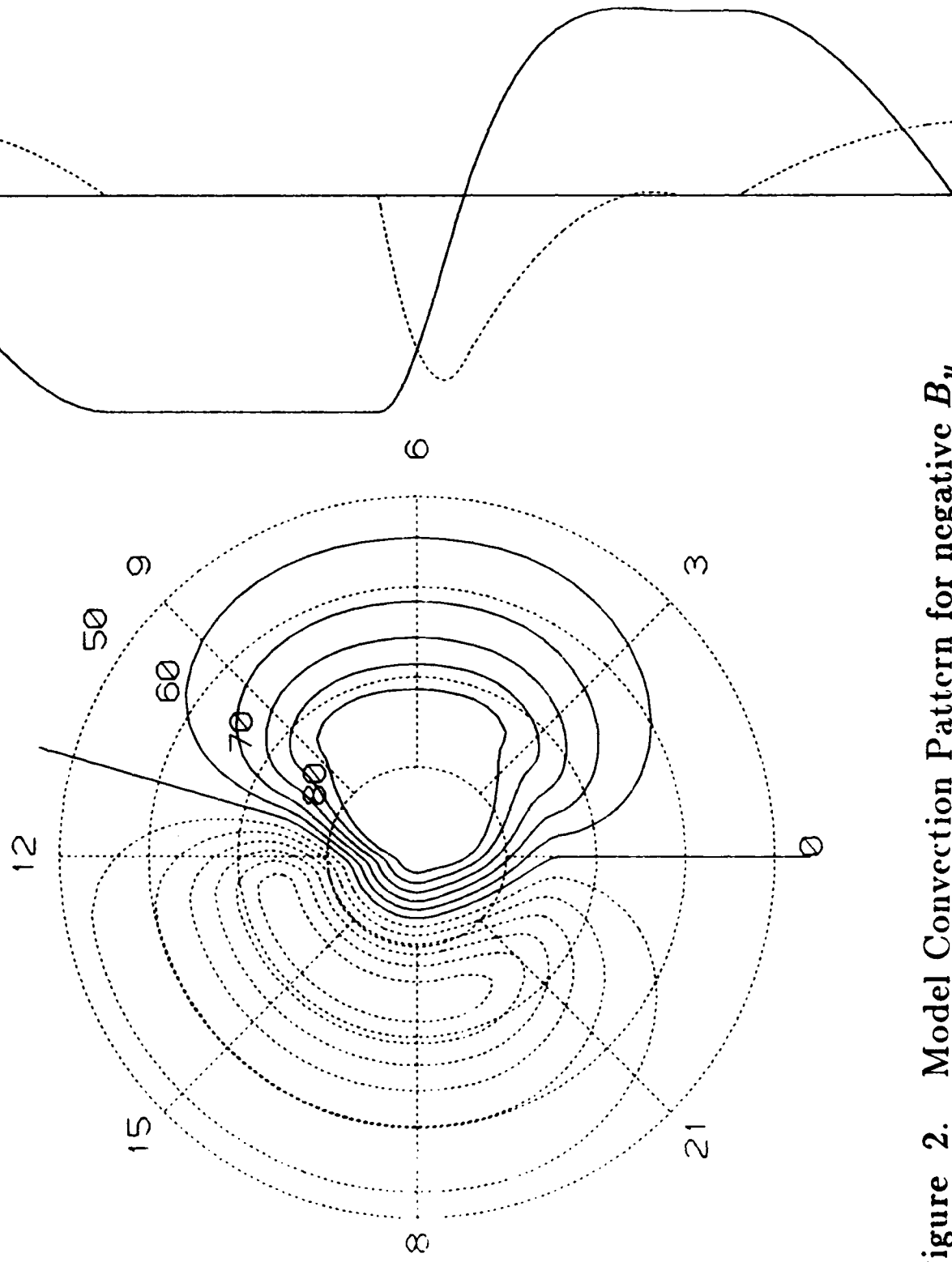


Figure 2. Model Convection Pattern for negative  $B_y$

#### 4. Small scale electrodynamics.

The appearance of plasma structure in the high latitude ionosphere is particularly important in its effects on the propagation of radio waves. The plasma structure has many production mechanisms and once produced, can be transported large distances by the convection electric field. During this contract we have examined the time dependence of small scale convective features capable of producing plasma structure and also the ability of such structures to evolve and produce other structures by communicating their electric field along magnetic field lines. We find that at the characteristic convection reversal associated with the two-cell convection pattern there frequently exist time dependent structures that may be capable of "stirring" the plasma concentration gradient across the reversal. The time dependence of such structures would allow plasma structure to be produced and removed from the region and subsequently transported to other regions. Our observations in this area are contained in paper 2 below. We also find that the existence of structure in the F-region plasma will produce "image" structures in the same flux tube at lower altitudes. The amplitude of the image structure is scale size dependent and since its production takes place at the expense of the higher altitude structure, the lifetime of the structure is also scale size dependent. These findings must be included in the evolution of plasma structure at high latitudes and in the explanation for a preferential scale size for the structure. It is also apparent that the E-region conductivity has a large effect on the production image structures and the lifetime of the high altitude plasma structure. Preliminary findings in this area are contained in paper 8.

Our work leaves open many avenues of new and further research efforts that we plan to pursue. In particular the convective configuration of sub visual

polar cap arcs, the creation of ionospheric structure by time dependent convection patterns and the evaluation of IMF dependences in convection pattern parameters all require further work that is already being undertaken. During this contract we have advanced many of these studies and the following publications have been completed with its support.

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P U B L I C A T I O N   A B S T R A C T S

### **MITHRAS: A brief description**

*O. de la Beaujardière,<sup>1</sup> V. B. Wickwar,<sup>1</sup> M. J. Baron,<sup>1,2</sup> J. Holt,<sup>3</sup> R. M. Wand,<sup>3</sup> W. L. Oliver,<sup>3</sup> P. Bauer,<sup>4</sup>  
M. Blanc,<sup>4</sup> C. Senior,<sup>4</sup> D. Alcaydé,<sup>5</sup> G. Caudal,<sup>4</sup> J. Foster,<sup>6,7</sup> E. Nielsen,<sup>8</sup> and R. Heelis<sup>9</sup>*

(Received July 19, 1983; revised October 28, 1983; accepted October 28, 1983.)

Between May 1981 and June 1982 an intensive campaign of 33 coordinated observations was carried out using the three incoherent-scatter radars capable of probing the auroral zone. During this period the groups operating the Dynamic Explorer satellites and the STARE radar made special efforts to acquire data coincident with the radar observations. The objective of these MITHRAS experiments and subsequent analysis is to further our understanding of the interactions of the magnetosphere, the ionosphere, and the thermosphere, with special emphasis on local time/universal time variations. Three experimental modes with different time resolution and spatial coverage were used to examine different aspects of these interactions. The analysis of the extensive data set involves collaboration among groups of experimenters as well as between experimenters and theoreticians.

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 89, NO. A3, PAGES 1627-1634, MARCH 1, 1984

## Velocity Spike at the Poleward Edge of the Auroral Zone

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Data from coordinated observations of the Chatanika incoherent scatter radar and the Atmosphere Explorer C satellite are examined to study the poleward edge of the auroral zone for one pass in the morning sector. A very intense, spikelike electric field is seen at the boundary between the auroral zone and the polar cap, coincident with the convection reversal. The particle detector data are consistent with the presence of a pair of oppositely oriented potential drops parallel to the magnetic field. These potential drops are of a few hundred electron volts, and their direction is such that the precipitating electrons are accelerated on the poleward side and decelerated on the equatorward side of the electric field spike. These observations are examined in the light of recent theoretical investigations that have shown that parallel acceleration can indeed be expected to occur in the regions of large velocity shear. The Chatanika data suggest that such spikes may occur repeatedly at the poleward edge of the diffuse aurora, but that they are confined in either time or space.

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 89, NO. A5, PAGES 2873-2880, MAY 1, 1984

THE EFFECTS OF INTERPLANETARY MAGNETIC FIELD ORIENTATION ON DAYSIDE  
HIGH-LATITUDE IONOSPHERIC CONVECTION

R. A. Heelis

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**Abstract.** The Atmosphere Explorer C data base of northern hemisphere ionospheric convection signatures at high latitudes is examined during times when the interplanetary magnetic field orientation is relatively stable. It is found that when the interplanetary magnetic field (IMF) has its expected garden hose orientation, the center of a region where the ion flow rotates from sunward to antisunward is displaced from local noon toward dawn irrespective of the sign of  $B_y$ . Poleward of this rotation region, called the cleft, the ion convection is directed toward dawn or dusk depending on whether  $B_y$  is positive or negative, respectively. The observed flow geometry can be explained in terms of a magnetosphere solar wind interaction in which merging is favored in either the prenoon northern hemisphere or the prenoon southern hemisphere when the IMF has a normal sector structure that is toward or away, respectively.

# ROCKET AND SATELLITE OBSERVATIONS OF ELECTRIC FIELDS AND ION CONVECTION IN THE DAYSIDE AURORAL IONOSPHERE

G. Marklund (1) and R. A. Heelis (2)

## Abstract

Electric field observations from two high-altitude rocket flights in the polar cusp have been combined with satellite observations of ion drifts to infer details of the electric field and convection pattern of the dayside auroral ionosphere. A region of shear flow reversal can be inferred from the electric field observations on one flight near 15.30 MLT 20 minutes after the Dynamics Explorer 2 satellite crossed through the same region. The drift patterns observed by the two spacecraft were very similar although shifted by 0.5 degrees, a shift which is expected from the observed change in the interplanetary magnetic field (IMF)  $B_z$  component during this time. A region of rotational flow reversal was covered by the other flight shortly after magnetic noon, at the same time the DE-2 satellite travelled along roughly the dawn-dusk meridian. By joining points of equal potential, integrated from the two datasets and assuming the reversal boundary to be an equipotential, the instantaneous convection pattern could be drawn showing crescent-shaped convection contours in the dusk cell and more circular shaped contours in the dawn cell. In order to reproduce this pattern using the convection model recently proposed by Heelis et al. (1982) it was found necessary to introduce a local-time dependence of the decay of the electric field with distance from the reversal boundary. Moreover this pattern is shown to be qualitatively in agreement with the predictions of a geometrical model by Crooker (1979) when the IMF is oriented towards dawn. The same characteristic patterns but with the dusk and dawn cells reversed, as pre-

sented in a recent radar-satellite study for the IMF oriented towards dusk may serve as additional evidence in favour of this model.

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INTERPLANETARY MAGNETIC FIELD EFFECTS ON  
HIGH LATITUDE IONOSPHERIC CONVECTION

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**ABSTRACT.** A description of the dayside ionospheric convection geometry is obtained from the study of satellite and ground-based radar data. The most dramatic differences in the convection signature are seen when comparing cases for northward and southward-directed interplanetary magnetic fields. When the IMF has a southward component it is found that for a normal garden hose orientation a dayside merging region exists on the morning side of local noon for both signs of  $B_y$ . The location of the merging region depends on the orientation of the IMF in the X-Y plane. The convection pattern is then characterized by a circular convection cell partially surrounded by a crescent-shaped convection cell. These cells occupy the dawn- and dusksides respectively for  $B_y < 0$  and reverse their positions for  $B_y > 0$ . When the IMF has a northward component, two convection cells exist entirely within the polar cap when  $B_y = 0$ . When  $B_y < 0$  a single anticlockwise circulating cell dominates the polar cap convection, and a single clockwise cell dominates when  $B_y > 0$ . These cells are displaced a little to the dusk- or dawn-sides respectively of the noon-midnight meridian. Evidence exists for additional convection driven by viscous interaction in all cases. The relationships between the observed ionosphere convection and plasma flow in the magnetosphere are discussed.

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## FUTURE CUSP EXPERIMENTS AND THEIR COORDINATION

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### ABSTRACT.

Our future progress will hinge upon: comprehensive complementary diagnostics at selected sites, coordination among selected chains of stations as well as with satellites, and effective interactive exchange between models and experiment. The locations, diagnostic capabilities, motivation, future research plans, and rationale for coordination is presented here for major sites, diagnostic complexes, and chains of stations key to future cusp experiments. The role of individual satellites is interwoven into the discussion, and the need for future multi-spacecraft programs underscored.

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## OBSERVATIONS OF MAGNETOSPHERIC CONVECTION FROM LOW ALTITUDES

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### ABSTRACT

Some of the observations and interpretive models that have provided a substantial increase in our knowledge of magnetospheric and ionospheric convection are discussed. While a two-cell convection pattern may be generally consistent with many ionospheric measurements, it is now clear that some significant departures from such a pattern must be considered. We can now specify more accurately the number of convection cells and their shape as well as the electrostatic potential distribution within the cells. All these factors can be shown to be sensitive functions of the interplanetary magnetic field (IMF). Interpretation of these findings in terms of the interaction of the earth's magnetosphere with the interplanetary medium has led to detailed consideration of the location of magnetic merging regions and the magnetic field topology of the outer magnetosphere. In addition, the relative importance of merging, viscous interaction and ionospheric processes in providing the driving force for convection has been considered. In general, the bulk of the driving force is magnetic reconnection; however, viscous processes play a significant role in times of northward interplanetary magnetic fields, and thermospheric drag may contribute to the maintenance of a convection pattern for several hours after such a northward turning.

ELECTRICAL COUPLING EFFECTS ON THE TEMPORAL EVOLUTION  
OF F LAYER PLASMA STRUCTURE

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**Abstract.** A time dependent model of F region structure decay by "classical" cross field diffusion and electrical coupling along magnetic field lines to the E region is examined. The temporal behavior of the ion concentration fluctuations is determined by the electric field in the coupled system as well as by the initial perturbation spectra and the E region recombination rate. The formation of image structure in the F region ion concentration affects the lifetime of F layer structure in a scale size dependent way. Once an image is formed, the image amplitude and the driving F region structure amplitude decay at the same rate. At large scale sizes,  $\lambda(\lambda=2\pi/k)$ , this rate is proportional to  $k^2$  and the ratio of the temperatures in each region. At small scale sizes it depends on the E region recombination rate and the temperatures of the two regions but is only very weakly dependent on  $k$ . The background E region concentration determines the wave number beyond which the structure amplitude decay rate is almost independent of its scale size.

A SUN-ALIGNED ARC OBSERVED BY DMSP AND AE-C

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**Abstract.** On May 12, 1977, 8 minutes after a DMSP satellite photographed a sun-aligned auroral arc in the southern polar cap, AE-C crossed over the same arc. Precipitating electrons were observed with a peak energy flux of  $0.94 \text{ erg cm}^{-2} \text{ s}^{-1}$  but with no clear monoenergetic beam, and coincident ion precipitation was measured at energies of a few keV. A very sharp ion convection reversal was found coincident with the particle precipitation and embedded in a region of constant antisunward flow. Magnetic field data indicate that the arc occurred during the recovery phase of a weak magnetic storm, with the IMF in a toward sector and the Z component nearly zero. The data are consistent with a source of particles at altitudes of the order of  $5\text{--}8 R_E$  on field lines containing the plasma sheet boundary layer. The electron spectra do not indicate the existence of an electrostatic potential along the magnetic field lines projecting from the arc. The electrodynamic properties associated with the arc appear to be consistent with a simple model in which field-aligned currents are required along any boundary where the horizontal ionospheric current diverges.

IONOSPHERIC CONVECTION SIGNATURES OBSERVED BY DE 2 DURING NORTHWARD INTERPLANETARY MAGNETIC FIELD

R. A. Heelis,<sup>1</sup> P. H. Reiff,<sup>2</sup> J. D. Winningham,<sup>3</sup> and W. B. Hanson<sup>1</sup>

**Abstract.** Observations of the ionospheric convection signature at high latitudes are examined during periods of prolonged northward interplanetary magnetic field (IMF). The data from Dynamics Explorer 2 show that a four-cell convection pattern can frequently be observed in a region that is displaced to the sunward side of the dawn-dusk meridian regardless of season. In the eclipsed ionosphere, extremely structured or turbulent flow exists with no identifiable connection to a more coherent pattern that may simultaneously exist in the dayside region. The two highest-latitude convection cells that form part of the coherent dayside pattern show a dependence on the  $y$  component of the IMF. This dependence is such that a clockwise circulating cell displaced toward dawn dominates the high-latitude region when  $B_y$  is positive. Anticlockwise circulation displaced toward dusk dominates the highest latitudes when  $B_y$  is negative. Examination of the simultaneously observed energetic particle environment suggests that both open and closed field lines may be associated with the high-latitude convection cells. On occasions these entire cells can exist on open field lines. The existence of closed field lines in regions of sunward flow is also apparent in the data.

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